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14. ABSTRACT The Future of the Pacific (FOP) program has sought to inspire the next generation of scientists and engineers by developing and implementing a multi-faceted STEM (Science Technology Engineering and Math) program for middle and high school students and teachers throughout the Pacific Region. The program's main focus has been Hawaii schools, specifically targeting underrepresented populations in STEM fields, including Native Hawaiian and Pacific Islander students as well as young girls and women. Within Hawaii, workshops and activities in the FOP program reached 275 teachers representing over 18,500 students, with a focus on inquiry learning methods and culturally-relevant STEM projects and activities for students with a broad spectrum of interests and abilities. Additionally, the program expanded in Asia-Pacific through a joint educational research pilot extending through 2014 with The Institute for the Promotion of Teaching Science and Technology in Thailand, training eight Thai and Lao PDR teachers in inquiry learning methods. The final program presentation, evaluation, and reflection were presented in Bangkok March 30-April 5, 2014. Results from this pilot phase included a 100% implementation rate in all recipient schools, with 37 activities presented to more than 350 students.						
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**Energy Inquiry: Hands-on, Inquiry Learning Methods  
to Enhance STEM Learning by Engaging Students  
in Renewable Energy Solutions  
(Research to Practice)**

**Strand: Engineering across the K-12 curriculum:  
Integration with the Arts, Social Sciences, Science,  
and the Common Core**

K-12 engineering education in the United States faces various challenges, from a seeming lack of interest in the field within American students to ongoing uncertainty among educators regarding how to develop and implement relevant curriculum standards. Despite these existing obstacles, Island Energy Inquiry<sup>TM</sup> (IEI), in existence since 2009, has introduced engineering concepts to more than 286 elementary, middle, and high school teachers and over 45,000 students across the state of Hawaii through a specially designed ad hoc science, technology, engineering, and math (STEM) integration approach as termed in *The Status and Nature of K-12 Engineering Education in the United States*.<sup>1</sup> IEI is a place-based, culturally competent Professional Development (PD) program that educates K-12 teachers and their students on renewable energy solutions—a highly relevant issue in the state—and builds STEM skills and methods through student-focused inquiry learning.

**Current uncertainties of K-12 engineering education in the United States**

STEM education and technological literacy are fundamental in the digital era. In recent years, educators and policy makers have reached a consensus that the teaching of STEM subjects in U.S. schools must be improved. The focus on STEM topics is closely related to concerns about U.S. competitiveness in the global economy and about the development of a workforce with the knowledge and skills to address technical and technological issues.<sup>1</sup> Several national trends are driving the advancement of engineering education within the United States. These trends include a declining interest among U.S.-born students in engineering, a decrease in national achievement in mathematics and sciences at pre-college levels, and a lack of technological literacy for all Americans. There are also predictions that there will not be a younger generation of U.S. citizens ready to replace science and engineering professionals nearing retirement age within the U.S. government.<sup>2</sup> In addition, students who do pursue engineering degrees do not reflect the diversity of students in the United States, a pattern of enrollment that is likely to have a number of negative consequences, both for the successful practice of engineering and for the resolution of broader societal issues. Concerns about the lack of engineering exposure for all children and ensuring a larger, more reliable supply of future engineers have been accompanied by the realization that we have not yet determined the best way to inform children of engineering skills and concepts.<sup>3</sup>

There is also continued debate on whether national standards should be developed and implemented for K-12 engineering education. A 2010 report by the National Academy of Sciences Committee on Standards for K-12 Engineering Education concluded that “...Although it is theoretically possible to develop standards for K-12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation.”<sup>4</sup> Alternately, several



states currently implement their own standards for K-12 engineering education. More states are expressing interest in this approach.<sup>5</sup>

United States educators at the classroom level also have mixed opinions regarding the status and potential of engineering education. A 2004 analysis by the ASEE Engineering K12 Center found that "...Overall, K-12 teachers have a positive attitude toward engineering."<sup>6</sup> However, when asked "How many of your students could succeed as engineers?" only 2.9% of responding teachers replied "all." As stated in the analysis, "Teachers are overwhelmingly positive about engineering in the abstract, extolling the virtues of an engineering education and career. However, when it comes down to their students, they believe that many—and especially females and minorities—cannot succeed in the engineering world."<sup>6</sup> Considering that female and minority groups will be dominating the U.S. workforce in the near-future,<sup>3</sup> this is a concerning attitude for educators to possess.

Despite the potential shortages in the future U.S. engineering workforce, lack of consensus regarding standards, and disparate attitudes held by educators about engineering education, there are a growing number of programs across the United States that incorporate engineering education into the classroom. Although these programs vary in their approach and context, they are making much-needed attempts to integrate essential engineering concepts in K-12 education. IEI falls within this cadre, providing a contextual foundation that innately connects engineering design to STEM activities by focusing on clean energy solutions, a topic that is highly relevant to the state of Hawaii and of interest to its students.

Responding to clean energy needs and regional workforce demands

Hawaii is more dependent than any other state in the nation on the importation of fossil fuel, currently importing 90% of its energy. Energy sustainability for this remote island chain will require reducing reliance on imported fossil fuels and a significant increase in reliance on renewable energy sources in the islands, such as wind, solar, geothermal, and wave energy.<sup>7</sup> In 2008, Hawaii made a public commitment to achieve 70% clean energy by 2030. An estimated thirty percent of this increase is expected to result from increases in energy efficiency. Hawaii's clean energy target is one of the most ambitious in the nation, and, if achieved, could serve as an example for the United States and the world.<sup>8</sup>

In order to meet the need for a talented clean energy workforce in Hawaii, local students must pursue educational and career pathways in the high-growth, high-paying STEM sector. Over the past 10 years, growth in STEM jobs [in the United States] was three times as fast as growth in non-STEM jobs.<sup>9</sup> STEM employment is expected to grow 17% between 2008 and 2018, outpacing the 10% growth projected for overall employment.<sup>9</sup> Also, the average annual wage for all STEM occupations was \$77,880 in May 2009, significantly above the U.S. average of \$43,460 for non-STEM occupations.<sup>9</sup> In the United States demand for STEM workers is unmet. In the STEM occupations, job postings outnumbered unemployed people by 1.9 to one.<sup>9</sup> These national workforce trends are also reflected in Hawaii, where projections indicate that there will be 29,000 STEM-related jobs to be filled by 2018.<sup>10</sup>

Despite the high demand for STEM workers and the incentive of well-paying careers, the United States still struggles to sufficiently educate its students in these fields. Only one in five STEM college students felt that their K-12 education prepared them extremely well for their



college courses in STEM.<sup>9</sup> Fewer than 40 percent of students who enter college intending to major in a STEM field complete a STEM degree.<sup>9</sup> A persistent gap continues between women and men pursuing STEM education and careers. A National Science Foundation survey found that in 2006, 15.1% of American female first-year college students majored in the STEM field, versus 29.3% of American male first year college students. The gender disparity in plans to major is even more significant when the biological sciences are not included. Just over one-fifth of male freshmen planned to major in engineering, computer science, or the physical sciences, compared to only about 5% of female freshmen.<sup>11</sup> However, there is hope to improve the numbers of females and underrepresented minorities in STEM fields, including engineering. Researchers believe that engaging, context-based engineering activities at the K-12 level could significantly increase the diversity of students who participate in STEM classes and ultimately pursue careers in these areas.<sup>12</sup> IEI uses inquiry methodology, applicable examples of engineering in industry, and inclusive kinesthetic activities to encourage students of all backgrounds to engage in engineering and experience its connections to STEM learning.

#### Island Energy Inquiry model: Renewable energy education via inquiry and design-based learning

Although there are a number of natural connections between engineering and other STEM subjects, existing curricula in K-12 engineering education do not fully explore them.<sup>1</sup> Building an education-to-workforce technical skills pipeline is critical to attaining clean energy goals both in Hawaii and the Asia Pacific region. The need for a regional renewable energy workforce with appropriate STEM skills presents a unique opportunity. IEI begins the process of preparing a local workforce that is knowledgeable in clean energy issues as well as STEM concepts through PD coursework that:

1. Utilizes inquiry learning to interest students in STEM.
2. Provides teachers with information on renewable energy progress in Hawaii.

IEI is a product of the Women in Technology Project (WIT), a workforce development program under the auspices of the Maui Economic Development Board. WIT has been building education programs in STEM for K-12 schools statewide for over ten years. In particular, WIT builds programs to engage underrepresented populations in STEM fields, including girls, women, and indigenous populations seeking to increase equity for all. IEI grew out of an annual Inquiry Science PD event for middle and high school science teachers. Recognizing the need for developing skills in energy science and connected STEM concepts, WIT developed the state's first renewable energy PD model which was initially piloted on Maui and then soon expanded to reach teachers statewide.<sup>7</sup>

The IEI model addresses the issue of the shrinking United States engineering workforce<sup>2</sup> through the following elements:

1. Highlights the three guiding principles of K-12 engineering education.<sup>4</sup>
2. Implements ad hoc and STEM integration approaches through flexible curriculum.<sup>1</sup>
3. Builds engineering education competence and shifts attitudes regarding STEM in teachers through professional development workshops, evaluation, reflection, resources, and ongoing program support.<sup>12</sup>
4. Increases STEM interest among females and underrepresented minorities through place-based application and local industry partnerships.<sup>12</sup>



1. *Highlights the three guiding principles of K-12 engineering education:*<sup>4</sup>

*A. Emphasizes engineering design.*

The engineering design process should be highly iterative and open-ended: promoting recognition that a problem may have many possible solutions; providing a meaningful context for learning scientific, mathematical, and technological concepts; and serving as a stimulus to systems thinking, modeling, and analysis.<sup>4</sup> An example within IEI's state-wide implementation illustrates the emphasis of engineering design in a unique environment—art class. Studio art teacher Janice Miyoshi-Vitarelli of Kalani High School on Oahu introduced the project “Celebrating Wind Energy,” directly based on IEI lesson 8.4, “Wind Turbine Design Inquiry.”<sup>13</sup> The goal of her project was to combine art and science in project-based learning. Although part of an art class, Miyoshi-Vitarelli's lesson was a clear example of engineering design and problem-solving methods.

In this instance, students were challenged to design, test, and redesign wind turbine blades, defining variables and measuring performance. Their goal was to optimize performance through design iterations, creating “functional design that adds beauty,” and basing form on the function of the blades themselves. Students were also required to model their design in stages, first sketching the blades and doing a design review with the teacher before earning approval for the next steps—sketching onto balsa, cutting and prepping unpainted blades, testing, modifying, and finally painting blades. This adheres closely to the guidelines of the Next Generation Science Standards (NGSS) Appendix F, Science and Engineering Practices in the NGSS:

“In engineering, models may be used to analyze a system to see where or under what conditions flaws might develop, or to test possible solutions to a problem. Models can also be used to visualize and refine a design, to communicate a design's features to others, and as prototypes for testing design performance.” Practice 2: Developing and Using Models.<sup>14</sup>

This example also addresses NGSS standard ETS1C: Optimizing the design solution.<sup>15</sup> In “Celebrating Wind Energy,” the teacher notes that the design, test, and redesign phase of the project enhanced the critical thinking and problem solving skills of her students. She also points out that following the design process empowered students as self-directed learners. And, at the project's conclusion, students were asked to reflect on their learning, to analyze their results and draw meaningful conclusions—individually and as part of two-person design teams.

*B. Incorporates important and developmentally appropriate mathematics, science, and technology knowledge and skills.*

Some science concepts, and some methods of scientific inquiry, can support the engineering design process. Some mathematical concepts and computational methods can also support engineering design, especially in the areas of analysis and modeling. Technology and technology concepts can illustrate the outcomes of engineering design, provide opportunities for “reverse engineering,” and encourage the consideration of social, environmental, and other impacts of engineering design decisions.<sup>4</sup> IEI teachers and their students are trained to use tablet technology to enhance their STEM knowledge and skills with the Hawaii Clean Energy iPad App, which was developed as part of the program. Students model a series of renewable energies including wind, solar, geothermal, biomass, and hydroelectric. In each model there are more than

one variable. For example, the wind farm activity enables the user to select number of turbines, individual turbine rated size, or wind speed to explore the system output in megawatts of electric power. Students are first challenged to ask questions, such as “What’s happened to output at low wind speeds?” or, “Is it ‘better’ to have more turbines, or larger turbines?” The app can be manipulated to explore these and other questions in maximizing and optimizing wind farm design.

Using iPads to explore engineering questions through Clean Energy App simulations appeals to modern students. With basic guidance from their teacher, students can soon find the value—and absolute importance—of selecting a single independent variable at a time in the quest to best develop a solution to their problem. This combination of rigor and discipline within a largely self-taught and self-directed simulation model is critical in helping students recognize the paths that engineers follow in pursuing the answers to infrastructural, environmental, and societal problems.

### *C. Promotes engineering habits of mind.*

Inquiry science, as adapted by IEI and WIT, pursues the following process:<sup>7</sup>

1. Has or obtains background information
2. States a problem and/or asks a question
3. Develops a testable hypothesis
4. Develops methods to test (establishes variables) and then tests
5. Analyzes results and makes conclusions

These five steps follow a cyclical pattern as new questions arise from conducted experiments. IEI’s inquiry process gives rise to engineering “habits of mind,” which include systems thinking, creativity, optimism, collaboration, communication, and ethical considerations.<sup>4</sup>

An example of this approach is IEI lesson 5.3, Solar Hot Water Heating.<sup>13</sup> In this activity, students are challenged to optimize a heat exchanger design, using solar energy to heat water. They coil a fixed length of clear plastic tubing within a black frame which has a single transparent surface. The pattern for tubing layout is left completely to the student team. During the first lab session, the exchanger is prepared and then connected to a small electric water pump which is itself driven by a photovoltaic panel. This gives students an opportunity to be sure their system is working and to make preliminary observations of the water heating effect.

As the initial system is observed and proven to be functional, student groups are asked to discuss possible variables affecting performance, and select a variable to test during the follow-on lab the next day. This team discussion is critical in understanding how engineers really develop their own investigations. From NGSS Appendix F - Science and Engineering Practices in the NGSS:

“In laboratory experiments, students are expected to decide which variables should be treated as results or outputs, which should be treated as inputs and intentionally varied from trial to trial, and which should be controlled, or kept the same across trials. In the case of field observations, planning involves deciding how to collect different samples of data under different



conditions, even though not all conditions are under the direct control of the investigator. Planning and carrying out investigations may include elements of all of the other practices.” Practice 3, Planning and Carrying Out Investigations.<sup>14</sup>

It is not enough that students merely know their solar hot water system works, although that is certainly important. They learn how the sun is heating water by providing energy to the photovoltaic panel, thereby powering the water pump electrically. But the true significance of this entire lab—the engineering practice they use and reinforce—is the ability to identify and control variables in a way that maximizes the effectiveness of their mechanical and thermodynamic system. It is these practices, skills, and abilities, developed under the teacher’s watchful eye, that help prepare our students for meaningful STEM careers. Inquiry learning goes beyond the transfer of scientific or engineering information and knowledge by empowering students to develop their own confidence in using the methods of working professionals.

## *2. Implements ad hoc and STEM integration approaches through flexible curriculum.<sup>1</sup>*

As termed in *The Status and Nature of K-12 Engineering Education in the United States*, ad hoc infusion, or introduction, of engineering ideas and activities (i.e., design projects) into existing science, mathematics, and technology curricula is the most direct and least complicated option [for engineering education], because implementation requires no significant changes in school structure. The ad hoc option is probably most useful for providing an introductory exposure to engineering ideas rather than a deep understanding of engineering principles and skills.<sup>1</sup> IEI closely aligns with the ad hoc approach because of its concept introduction to teachers who have little or no previous exposure to engineering education. On a smaller scale, IEI follows the STEM education integration approach, using engineering concepts and skills to leverage the natural connections between STEM subjects<sup>1</sup> through its scientific inquiry foundation and connections to multiple facets of STEM. IEI promotes the scientific inquiry process throughout its curriculum, gives teachers and students the opportunity to simulate various clean energy systems and hone their technology skills with the Clean Energy iPad App, utilizes engineering design concepts by building different clean energy apparatuses, and prompts students to use mathematical formulas to calculate data they collect in experiments. IEI only serves a minor role in this overall approach, however, because its intensive implementation, which includes “changes in school structures and practices”<sup>1</sup> is beyond the scope of the program.

The IEI curriculum is a vehicle for teachers across the state to teach students STEM concepts while incorporating highly relevant information about renewable energy data, design, and resources. It maintains a place-based foundation, providing examples that are relevant to Hawaii’s geography, climate, and culture. IEI encourages students to use critical thinking skills to solve problems, to ask relevant questions about the subject matter they are learning, and to successfully apply theoretical concepts to real-world challenges through hands-on educational activities.

IEI educators play a key role in facilitating the curriculum’s inquiry process, guiding students through its steps and supporting classroom discussions that occur. It has been found that the IEI curriculum allows flexible modification and implementation for participating teachers from a variety of backgrounds. Teachers not only come from STEM subject areas, but also language arts, fine art, social studies, and career and technical education.

3. *Builds engineering education competence and shifts attitudes regarding STEM in teachers through professional development workshops, evaluation, reflection, resources, and ongoing program support.*<sup>12</sup>

The delivery of IEI extends beyond the experience of the training workshop itself. To earn credit as an implementer, each teacher must reflect on lessons learned in the classroom and share with peers. Some teachers report that this is the most valuable step in learning to use IEI—taking the time for meaningful reflection, and developing conclusions from their own teaching that represent value to other teachers pursuing inquiry learning techniques:

“Overall, this course has become much more beneficial to me as a teaching practitioner over the past few days in reflection than I would have imagined. The workshop was hands-on and informative, the presentations and feedback sessions brought more “realness” to the application and the learning process of the inquiry activities, and the reflections especially, have forced me to dig deep to find the relevance and meaning to this workshop in accordance to my personal and professional life.”

*Kellie Takamori, Grade 7 Math, Kalakaua Middle School, Oahu, January 2014*

4. *Increases STEM interest in females and underrepresented minorities through place-based application and local industry partnerships.*<sup>12</sup>

IEI provides gender equity training and focuses on the inclusion of underrepresented minorities to achieve the overarching goals of gender parity and increased diversity in the STEM field. This includes take-home reading assignments and allocated time for group discussion among IEI participants about concrete strategies for pursuing parity in STEM success.

Since IEI’s beginning, local industry professionals from wind, solar, geothermal, ocean thermal energy conversion, biofuel, and energy conservation have presented at IEI’s workshops, providing highly accessible evidence of the local renewable energy industry and showcasing Hawaii as a premier clean energy test bed.

Table 1 <i>Renewable Energy IEI Workshop Presentations by Island, November 2012-October 2013</i>			
Maui	Oahu	Kauai	Hawaii Island
Energy Conservation (Hawaii Energy, November 2012, June 2013)	Wind Turbine Basics (Hawaii Electric Company/First Wind, January, March, May, October 2013)	Energy on Kauai (Kauai Island Utility Cooperative, January 2013)	Geothermal Energy (Puna Geothermal Venture, January 2013)
Sun Power for Schools (Maui Electric Company, November 2012)	Energy Conservation (Hawaii Eco Project, January, March, May, October 2013)	Solar Energy Resources (Kauai Community College, January 2013)	Biodiesel Fuel (Pacific Biodiesel, January 2013)
Wind Turbine Basics (Auwahi Wind Farm, June 2013)	Algal Biofuels (Blue Planet Project, January, March, May, October 2013)		



Table 1 Continued			
Maui	Oahu		
Bagasse as Energy (HC&S, June 2013)	Ocean Thermal Energy Conversion (Makai Ocean Engineering, January, March, May 2013)		
Biofuel Energy (Pacific Biodiesel, June 2013)			

The local industry professionals who present at IEI workshops are mainly from engineering, science, and agriculture technology backgrounds. Educators take resources from these presenters and inform their own students about current renewable energy trends in Hawaii. This method provides a high-impact expansion of statewide knowledge in renewable energy, offers local industry leaders the opportunity to improve or maintain their organization's public image, and provides the essential connection between education and industry that shows students the emerging career possibilities in renewable energy and STEM.

#### Applicability and expansion

Since IEI's five pilot workshops in 2009, the program has significantly expanded its reach. From November 2012 to October 2013, 125 STEM teachers from eight two-day IEI workshops experienced an 85% success rate in launching and sharing results from curriculum-based labs and activities. In this eleven month period, 43.7% of the total 286 IEI participants were trained.

As part of its ongoing evaluation process, IEI administers pre- and post-workshop participant assessments, utilizing audience response systems technology to instantly record and save results. Assessments are designed by IEI WIT staff in consultation with a retained external project evaluator. The IEI workshop pre-assessment mainly focuses on the enrolled educator's demographic information and intentions regarding attending the workshop. Key results of the pre-assessment of 120 educators that participated in the IEI workshops from November 2012 through October 2013 are presented below.

Table 2 <i>Island in which IEI Participant Resides:</i>			
Maui, Molokai, Lanai	Oahu	Kauai	Hawaii Island
26.7%	60.8%	3.3%	9.2%

The majority of IEI participants reside on Oahu, which is to be expected because it is the island with, by far, the highest population in the state. Demand for IEI workshops was also the highest from Oahu educators, with four of the eight IEI workshops occurring on the island.

75.4% IEI workshop teacher participants were women and 24.6% were men. The classroom gender mix among IEI student participants was teacher reported as follows: 87.3% "fairly even mix of boys and girls," 11.9% "all or mostly boys," and 0.8% "all or mostly girls."

Table 3

*IEI Participant Grades Taught:*

Grade 1-2	Grade 3-4	Grade 5-6	Grade 7-8	Grade 9-10	Grade 11-12
0.9%	5.2%	27.6%	31.9%	19.0%	15.5%

The IEI curriculum's units focus on educational benchmarks for grades 5-8. This is reflected in IEI student demographics with 59.5% of participants teaching grades 5-8. Although the IEI curriculum was originally created for intermediate-level students, there is frequent implementation of the lessons and concepts by higher-level educators, with 34.5% of IEI participants teaching grades 9-12. One of IEI's strengths is its applicability to various grade levels and subject areas. Because of the diverse backgrounds of the IEI participant teachers, students across disciplines are introduced to engineering design concepts and scientific inquiry methodology through IEI activities, such as wind turbine building, energy auditing, and solar power system design.

Finally, 61.8% of IEI participants stated their reason for attending the workshop was because they were "interested in energy on our islands." This demonstrates the demand for information and resources about renewable energy in the region. Providing educator resources, training, and tools meets that need and increases the future workforce's capacity in energy and STEM through lesson implementation.

IEI post-assessments focused on how participants' capacity improved in inquiry learning methodology, clean energy knowledge, and understanding gender influence in classroom education. Out of 105 participants who attended the two-day workshops and completed the post-assessment, the following results were found:

Table 4

*"I have improved my ability to implement inquiry-based science."*

Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure
45.2%	54.8%	0.0%	0.0%	0.0%

Table 5

*"I have a clearer understanding of energy sources and uses in Hawaii."*

Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure
73.3%	26.7%	0.0%	0.0%	0.0%

Table 6

*"Energy education in Hawaii's science classes is:"*

Very Important	Somewhat Important	Mostly Unimportant	Unimportant	Not Sure
89.5%	10.5%	0.0%	0.0%	0.0%



Table 7

*"I am more confident in my methods to involve girls and under-represented groups in science learning."*

Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure
22.9%	64.8%	6.7%	1.0%	4.8%

Table 8

*"I would recommend this course to other Hawaii-based teachers in my field."*

Strongly Agree	Agree	Disagree	Strongly Disagree	Not Sure
90.5%	7.6%	1.0%	0.0%	1.0%

100% of respondents strongly agreed or agreed that they had "improved [their] ability to implement inquiry-based science." 100% of respondents strongly agreed or agreed with the statement, "I have a clearer understanding of energy sources and uses in Hawaii." 100% of respondents also replied that "energy education in Hawaii's science classes is" very important or important. 91.4% of participants strongly agreed or agreed that they "have a clearer understanding of gender influences on science learning in the classroom," and 87.7% of respondents strongly agreed or agreed with the statement that they are "more confident in [their] methods to involve girls and under-represented groups in science learning. Finally, 98.1% of respondents strongly agreed or agreed that they "would recommend this course to other Hawaii-based teachers in [their] field."

Qualitative data also resulted from teacher responses in their Hawaii DOE Learning Results Portfolios (LRPs), which include the following elements:

- Lesson Plan 1
- Six Student Reflections, Lesson 1
- Teacher Reflection, Lesson 1
- Lesson Plan 2
- Six Student Reflections, Lesson 2
- Teacher Reflection, Lesson 2
- Teacher Culminating Reflection (impacts of course implementation on teacher methods)
- Teacher pre- and post-course surveys

The following is a sample of quotes from LRP teacher reflections:

"The Island Energy Inquiry workshop and lessons were so amazing. I plan on doing these lessons and expanding on them every year...I will add more inquiry-based activities to my lessons knowing that students learn so much because of the high motivation generated by these concrete activities."

*Carolyn Bush, Grade 4, Kamalii Elementary School, Maui, November 2013*

“After attending the workshop this summer, I returned to school with renewed motivation to teach science...I found the focus on Hawaiian energy issues to be the most beneficial...When students see the relevance of the science they are learning about in their own home, community and state, their enthusiasm for learning increases dramatically.”

*Robert Tenison, Grade 11 Chemistry, King Kekaulike High School, Maui, October 2013*

“The activities were attention-grabbing and the students became determined to finish and focus on completing the work. Independently, they were able to generate an inquiry and more importantly, complete the inquiry as self-directed learners.”

*Harvey Llantero, Grade 8 Science, Washington Middle School, Oahu, November 2013*

“For my female students, this was one of their first experiences with electronics and tools. Watching them build circuits and feel comfortable with tools such as wire strippers and motors was empowering to me...This course reminded me of the type of teacher I wanted to be when I first entered this profession. Having the ability and resources to guide students through labs that demonstrate real-life physics and science concepts strengthens my own practice.”

*Joanna Kobayashi, Grade 9 Basic Physics, Moanalua High School, Oahu, April 2013*

“Our student discussions were anything but boring...Having the IEI training has enlightened me to more of my own potential of being able to run project-based-learning. Having the IEI lesson plans makes it very doable, very practical to teach math through inquiry learning.”

*Cynthia Van Kleef, Grade 7 Math, Iao Intermediate School, Maui, September 2013*

These results display the effectiveness of IEI in its capacity to augment inquiry-based teaching skills in educators that teach a variety of subject areas while highlighting current placed-based clean energy issues and resources.

#### Addressing educational standards

In addition to increased implementation rates and overall reach since 2009, IEI’s dynamism is evidenced by its integration of institutional education standards. Furthermore, IEI’s structure naturally integrates engineering concepts within these existing standards, allowing teachers greater capacity for implementation. As a Hawaii DOE PD course, IEI has addressed the Hawaii Content and Performance Standards (HCPS III) in Science as part of its implementation process. More recently, IEI has adopted the Common Core State Standards Initiative (CCSS) as well as the NGSS, based on the framework for K-12 Science Education and developed by the National Research Council.

Each IEI curriculum unit addresses HCPS III for Science. An example of this is displayed in Table 9, in which wind energy is used as a platform topic for HCPS III benchmarks:<sup>13</sup>

Table 9 <i>Unit Overview: Island Breezes Blowing Energy</i>			
Lesson	Title	Essential Question	HCPS III Benchmarks for Science
1	Wind Power Basics	How does wind energy turn a simple turbine?	SC.8.1.1 SC.8.1.2



Table 9 Continued			
Lesson	Title	Essential Question	HCPS III Benchmarks for Science
2	The Earth's Wind Patterns	Why does the Earth have wind patterns?	SC.8.8.3 SC.8.8.4 SC8.8.6
3	Wind Projects for Hawaii	How are wind farms in Hawaii currently producing energy for the state?	SC.8.2.1
4	Wind Turbine Design Inquiry	What are the most efficient turbine designs?	SC.8.1.1 SC.8.1.2
5	Energy Sustainability for Hawaii	How can harnessing wind energy impact the future energy sustainability of Hawaii?	SC.8.2.1

- SC.8.1.1: Determine the link(s) between evidence and the conclusion(s) of an investigation
- SC.8.1.2: Communicate the significant components of the experimental design and results of a scientific investigation
- SC.8.8.3: Describe how the Earth's motions and tilt on its axis affect the seasons and weather patterns
- SC.8.8.4: Explain how the sun is the major source of energy influencing climate and weather on Earth
- SC8.8.6: Explain the relationship between density of convection currents in the ocean and atmosphere
- SC.8.2.1: Describe significant relationships among society, science, and technology and how one impacts the other

IEI also offers interdisciplinary HCPS III benchmarks as resources for teachers in Math (MA), Language Arts (LA), and Technical and Career Education (CTE). These include but are not limited to:<sup>13</sup>

- MA.8.11.2: Judge the validity of data based on the data collection method
- MA.8.14.1: Judge the validity of conjectures that are based on experiments or simulations
- LA.8.1.2: Use a variety of grade-appropriate print and online sources to research an inquiry question
- LA.7.7.3: Use precise vocabulary suited to topic and audience
- CTE.8.1.1: Assess the overall effectiveness of a product design or solution

IEI will be selecting benchmarks from among the CCSS for Reading and Math and applying them to the next edition of IEI Curriculum Guide. An IEI pilot module that has been tested in local schools addresses the CCSS Writing Standards, Text Types, and Purposes: *Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.*<sup>16</sup> Students must critically analyze literature and media

regarding controversies in smart grid technology, an issue that is highly relevant to the Maui community.

Although Hawaii is only in the preparation process of adopting the NGSS, several benchmarks will be included in the next edition of the IEI curriculum:<sup>17</sup>

NGSS Physical Science—

- PS1A: Structure and properties of matter
- PS2A: Forces and motion
- PS3A: Definitions of energy
- PS3B: Conservation of energy and energy transfer
- PS3C: Relationship between energy and forces
- PS4B: Electromagnetic radiation
- PS4C: Information technologies and instrumentation

NGSS Engineering, Technology, and Applications of Science—

- ETS1A: Defining and delimiting an engineering problem
- ETS1B: Develop possible solutions
- ETS1C: Optimizing the design solution

IEI's ability to adopt new and evolving educational standards offers teachers a curriculum that incorporates engineering education concepts while providing progressive pedagogy and necessary benchmarks that appropriately measure student and institutional progress.

## Conclusion

IEI successfully awakens the natural engineer in students, showing them and their teachers that everyone can appreciate the methods and achievements of career engineers. The curriculum's ad hoc, STEM integration approach makes engineering and STEM a more accessible topic for all students by including gender equity discussion and a culturally-relevant context. IEI teachers use the techniques of inquiry learning, inspiring young people to ask their own questions, develop, revise and optimize designs, and seek solutions individually and in teams—the essence of engineering design. The hands-on nature and variety of materials used in IEI to model renewable energies can show students how to apply mathematics while also helping them understand that technology is much wider in scope than computers and cell phones. Because energy is particularly expensive in their locale, IEI students motivate towards lab activities that emphasize renewable energy and energy efficiency, linking classroom learning to the needs in their home community.

A well-educated and prepared future STEM workforce is essential to meet Hawaii's goals of 70% clean energy by 2030.<sup>8</sup> Simultaneously, there is a serious current and projected shortfall in the STEM education pipeline, especially among women and minorities in the engineering field. Teachers find that the techniques IEI employs to reach young females and under-represented groups can boost motivation and enjoyment for all their students. Tying learning to both culture and place makes classwork meaningful and relevant. Even as standards and national teaching methods are being explored, IEI gives K-12 educators a dynamic and proven teaching



model in showing the value of STEM careers to our next generation of young scientists and engineers.

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Asia Pacific Energy Inquiry:

Applying Relevant STEM Learning Techniques and Content at the International Level

DeVey, G., Bristol, L., Wilkins, L.

Maui Economic Development Board's Women in Technology Project

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### List of Acronyms

- **AEDP:** Renewable and Alternative Energy Development Plan for 25 Percent in 10 Years
- **APEI:** Asia Pacific Energy Inquiry
- **AREW:** Asian Renewable Energy Workshop
- **IEI:** Island Energy Inquiry
- **IPST:** Institute for the Promotion of Teaching Science and Technology
- **Lao PDR:** People's Democratic Republic of Laos
- **MEDB:** Maui Economic Development Board
- **MW:** Megawatts
- **NEA:** National Education Act
- **NESRS:** National Education System Reform Strategy
- **ONR:** Office of Naval Research
- **PD:** Professional Development
- **STEM:** Science, Technology, Engineering, and Math
- **WIT:** Women in Technology Project

## Introduction

Asia Pacific Energy Inquiry (APEI) is a science, technology, engineering, and math (STEM) pilot learning program that helps students discover the sciences of renewable energies and connect with energy advances in the Asia Pacific region. The program educates students in STEM concepts through inquiry methodology.

APEI was adapted from a Hawaii, United States STEM energy curriculum known as Island Energy Inquiry<sup>TM</sup> (IEI). IEI was originally created in 2009 by the Maui Economic Development Board's (MEDB) Women in Technology Project (WIT) with funding from the United States Office of Naval Research (ONR) to increase STEM literacy in the state and educate students on clean energy solutions, a highly relevant local issue. IEI is a place-based, culturally competent Professional Development (PD) program that educates K-12 teachers and their students on renewable energy solutions and builds STEM skills and methods through student-focused inquiry learning (Wilkins, Bristol, DeVey, 2014, p.1).

IEI is a product of the Women in Technology Project, a workforce development program under the auspices of the Maui Economic Development Board. WIT has been building education programs in STEM for K-12 schools statewide for over ten years. In particular, WIT builds programs to engage underrepresented populations in STEM fields, including girls, women, and indigenous populations seeking to increase equity for all. IEI grew out of an annual Inquiry Science PD event for middle and high school science teachers. Recognizing the need for developing skills in energy science and connected STEM concepts, WIT developed the state's first renewable energy PD model which was initially piloted on Maui and then soon expanded to reach teachers statewide (Papini-Warren, Wilkins, 2011, p.3). Since its inception IEI has introduced science and engineering concepts to more than 286 elementary, middle, and high school teachers and over 45,000 students across the state of Hawaii.

The Mission Statement for APEI is as follows:

*"A pilot program to explore and share universal learning techniques in a global setting."*

In this case, the "universal learning techniques" refers to the Hawaii-based IEI PD course. The state of Hawaii has neither a centrally-developed method for teaching inquiry learning, nor an established curriculum to address renewable energy teaching and learning. Yet, the high prices of energy, particularly electricity from the grid, attract to Hawaii many research activities and commercial start-ups associated with renewable energies. IEI focuses on inquiry learning activities while sharing renewable energy data with teachers and providing links to academic and industry research in the field.

The success of IEI within Hawaii and the nature of its interaction with teachers suggest the lessons of IEI should readily adapt to other global cultures where inquiry learning is



important and conversion from conventional fuels to renewable energy is a goal for the community.

In May 2013 ONR and the United States Department of State recruited WIT to transfer the IEI curriculum to recipient schools in Thailand and Lao PDR. WIT partnered with the Institute for the Promotion of Teaching Science and Technology (IPST), located in Bangkok, Thailand, to locally apply the program, now titled APEI. Seven educators from Thailand and one educator from Lao PDR participated in the pilot program. The initial APEI PD workshop was held in Bangkok, Thailand, September 2-5, 2013. Ongoing support to APEI participants was provided thereafter, and the final program presentation, evaluation, and reflection were presented in Bangkok March 30-April 5, 2014. Results from this pilot phase included a 100% implementation rate in all recipient schools, with 37 activities presented to more than 350 students. This paper will present how the APEI program reached its pilot phase goals to successfully integrate with the current economic, energy, and education conditions of Thailand and Lao PDR.

### **Economy, Energy, and Education in Thailand and Lao PDR**

Thailand and Lao PDR have distinct histories and are currently at unique economic development stages. Both countries' backgrounds were carefully considered in the development and implementation of the APEI pilot.

As stated by the World Bank (2014) Thailand became an upper-middle country in 2011. Notwithstanding political uncertainty and volatility, Thailand has made great progress in social and economic issues. As such, Thailand has been one of the great development success stories, with sustained strong growth and impressive poverty reduction. However, some regions—particularly the North and Northeast—and some ethnic groups lag greatly behind others, and the benefits of economic success have not been shared equally. In 2011 Lao PDR moved up from its previous lower income status to become classified as a 'lower-middle income economy.' At this pace, Lao PDR is on track to achieve its long term vision: to graduate from the Least Developed Country status by 2020 (World Bank, 2014).

Energy demand increases have coincided with rapid economic growth in Southeast Asia including Thailand and Lao PDR. In Thailand, even with increasing domestic energy production, energy imports continue to be very significant. 2011 data find that over 60% of primary commercial energy demand [is] derived from importation. 80% of domestic oil consumption was imported oil. This trend is increasing since domestic petroleum production is not enough to meet in-country demand (DEDE AEDP, 2012, p. 1). Concerns about dependence on energy imports has resulted in the Thai Government developing the Renewable and Alternative Energy Development Plan for 25% in 10 Years (AEDP), which aims have Thailand using 25% renewable energy out of their total energy consumption (DEDE AEDP, 2012, p. 3). Renewable energy sources to be included in this plan include:

- Tidal Wave: 2 Megawatts (MW)
- Geothermal: 1 MW
- Solar: 2,000 MW
- Wind: 1,200 MW
- Hydropower: 6,108 MW
- Bio Energy: 4,390 MW
- Bio Fuel: 44% replacing oil

*(Source: DEDE AEDP, 2012, p. 3)*

Robust strategy was also created to achieve the goals of AEDP. A major component of this as stated by AEDP is “Promoting the community to collaborate in broadening [the production and consumption] of renewable energy.” APEI’s program goal to educate students in renewable energy resources and production strongly connects to this AEDP strategic point. Renewable energy infrastructure development must be supported by a knowledgeable participating community.

Lao PDR has low conventional energy consumption. Wood fuels consumption in 2002 was 2.4 million tons and accounted for 69% of total energy consumption (Theuambounmy, p. 1). Lao PDR’s government energy policy includes prioritizing rural electrification with the objective to achieve 90% electrification by 2020 (Theuambounmy, p. 3). However, as electrification spreads to more rural areas, connecting to a centralized grid becomes a greater challenge. In response to this issue, the Lao Government has promoted off-grid delivery models which favor renewable technologies. [Lao PDR] has significant solar and wind resources as well as hydroelectric and biomass fuels (Theuambounmy, p. 2). Commercial photovoltaic (PV) activities are already present in Lao PDR (Theuambounmy, p. 3). While Lao PDR lags in its renewable energy development in comparison to Thailand, the country has great potential to utilize a diverse array of renewable energy resources to meet demand and support socio-economic development, particularly in rural areas (Theuambounmy, p. 6). It is important that communities that will be experiencing these energy advances understand the technologies involved and can be active contributors to the process.

Thailand and Lao PDR both view education as an essential foundation to successful economic development. As stated by Chalapati, “Development orthodoxy promoted by the World Bank and Asian Development Bank emphasizes a conceptual link between education and poverty alleviation” (2008, p. 3). Education is now also regarded as a means to prepare Thais for work in the new global knowledge economy. There is a belief that each country’s social, political, and economic future in the world system is directly connected to their education success at home (Chalapati, 2008, p. 4).



Thailand's Government has made efforts to implement nation-wide education reform in order to shift the classroom environment from rote methods to student-centered learning. This is based on the belief that education is vital for economic vitality, especially in a globalized, knowledge-based world (Hallinger & Lee, 2011, p. 139). In 1999, Thailand passed the National Education Act (NEA) in 1999. As stated by Hallinger and Lee (2011, p. 140), "This law set new educational goals and sought both legitimize and stimulate the reform of teaching and learning methods, school management systems, and the legal framework of education in Thailand." Preliminary studies have found the NEA reform to have mixed success across the country, with individual teachers widely varying in their teaching pedagogy evolution.

The modern Lao education system is relatively new, with the country's first formal school established in 1902 (Itoh & Pouttha, 2005, p. 10). Despite external occupation and various periods of instability, over the last 20 years the national education system has gradually improved in terms of quantity and quality along with the introduction of a market economy (Ministry of Education, 2008, p. 2). The National Education System Reform Strategy 2006-2015 (NESRS) was developed to clarify nation-wide education goals and objectives. APEI's renewable energy and STEM education program coincides with multiple elements of the NESRS, including contributing to the transfer to industrialization and modernity, encouraging foundations in the scientific approach, being good citizens, educated, knowledgeable, employed, capable, innovative, creative, and enthusiastic about the development of the country (Ministry of Education, 2008, p. 7).

As described above, Thailand and Lao PDR have both experienced significant economic development in recent decades, albeit at varying levels. Increased energy consumption patterns have initiated demand for resources such as petroleum which currently cannot be met in-country, as is the case with Thailand. Concerns about energy dependence and a desire to strengthen national economies have motivated Thailand and Lao PDR to both develop their renewable energy resources and make national education reforms that are focused on student-centered learning and participating in a globalized world. This consequently leads to an increased demand for a workforce with the STEM skills to work in a knowledge-based industry such as renewable energy development and production. APEI addresses these needs by presenting applicable, relevant educator PD training, promoting local energy industry connections, and providing ongoing support in renewable energy and STEM-focused lesson implementation.

### **APEI Program Overview**

APEI was launched through a four-day workshop for teachers held at IPST facilities in Bangkok from September 2-5, 2013. This workshop was carefully crafted to achieve several results:

1. Teachers were guided through hands-on science lab activities to experience how their students can learn inquiry science—doing as scientists do—through a sequence of explorations.

Early in the workshop, following some basic introductions, teachers were immediately challenged to think, behave, and act very much like young science students. A very simple, pinwheel-building and testing lab encouraged them to follow written instruction without much instructor guidance, and to help each other to develop a pinwheel model (a simple paper wind turbine) for testing. Workshop staff, together with experienced teachers from Hawaii, gave the new APEI teachers just enough procedural clues to help them succeed but also to take pride in their own work and their own discoveries.

With the pinwheel models built and tested in a simple way, the group discussed the word “variable” and listed all possible variables they noticed during the lab testing. The difference between dependent and independent variable was made clear.

Then, teachers were asked to re-design the test itself. They were forced to choose one variable to test—the independent variable—and to make a hypothesis about that variable. All other possible variables became constants, carefully controlled so they would not impact the experimental outcome or affect the dependent variable.

As teachers reported the results of the test they had developed, the team shared ideas about the learning process—how scientists develop experiments to answer basic questions, and how they revise their testing, and their hypothesis, depending on successive results.

The APEI group spent time discussing the “Inquiry Science” diagram, as modified by MEDB (located in Appendices) and discussed verbal and iPad examples available through MEDB’s Clean Energy software application.

During all four days of the workshop, a variety of hands-on labs followed the pattern of the pinwheel activity. APEI teachers built and tested photovoltaic panels, wind turbines, energy audit meters, and solar water heaters. But each time, they followed an initial test with one or more re-designs of the experiment, in order to test a particular variable of their choice. Teachers were challenged again and again to ask and answer their own questions through experimental design, and to learn as scientists do.

The goal of this type of experimentation was to have teachers imagine all their students in the roles of scientists, and to gain confidence in helping them design experiments within the classroom setting. The immersion and success of students in scientific inquiry was the most important, fundamental lesson of the APEI workshop.



2. Teachers were given access to up-to-date status of renewable energies in their home countries.

Regarding educational content, APEI teachers were given a brief but accurate overview of energy sources and uses in Thailand and Lao PDR, plus links and connections to similar information. Also, national goals for renewable energy introduction, and progress toward those goals, were highlighted. The purpose of this part of the workshop was to establish a consistent body of data for our teachers to use in instructing students—as a background for the inquiry labs students will be conducting.

3. Teachers were connected to professionals working in renewable energies.

Beyond the basic renewable energy data that was shared in the workshop, APEI teachers met with and learned directly from academic or industry professionals. There are many classrooms of students spread throughout Thailand and Lao PDR, and to have such professionals visit each classroom to inspire students is not practical. However, the eight attendees of the workshop represent perhaps 1500 students annually. Through the workshop, APEI teachers learn the latest technical progress in several renewable energies directly from experts. They can then go to their classrooms, put the lessons into their own wording, and enhance student learning in an effective way. Also, APEI teachers learned of websites and links to these professionals and their organization, in order to follow closely the progress taking place in the technical community of renewable energies.

4. Teachers were enabled to develop the first two APEI classroom lessons, ready to launch in their schools.

From IEI workshops in Hawaii, data suggests that teachers need to attempt lessons in their own classrooms within a few weeks of workshop completion. Otherwise, as time passes, the motivation to try inquiry learning can fade, and teachers may never implement the lessons at all. Therefore, the APEI teachers were given help on the final day of the workshop to select and develop at least two inquiry-based, hands-on lab activities for their classroom.

When APEI teachers returned to the classroom, MEDB and IPST representatives contacted the individual participants to monitor their progress. This was an important step. Within Hawaii, IEI teachers actually join online, internet-based forums about six weeks after workshops to present to one another in small groups of ten or twelve teachers. During such sessions, each IEI teacher shares photos and lesson plans while others offer encouragement, suggestions, and possible improvements. Graduates of IEI have said that these sharing opportunities are a highlight of their implementation and are very valuable to their progress as inquiry teachers.

Online sharing among APEI teachers remains as a possible opportunity. Instead, a group of several APEI teachers met informally in Chiang Mai during the Asian Renewable Energy

Workshop (AREW) in December, and a second group met in April just prior to the APEI Awards Ceremony in Bangkok. During these two sessions, teachers openly described their experiences introducing Energy Inquiry with their students. Which lessons were tried, as well as the attitudes expressed by teachers and their students, are summarized in the Results and Discussion of this report. However, at the two informal review sessions, teachers expressed their enjoyment of these lessons and their support for expanding the implementation of inquiry learning activities.

5. Teachers were given lab kits and curriculum guides to undertake inquiry learning within their coursework

For this first workshop pilot project each APEI teacher was given a set of individual lab materials suitable for about six lab teams. Also, teachers gained access to online curriculum, worksheets, video tutorials, and expanded resources. The teachers received “hard” copies of the printed curriculum guide and CD and DVD versions of videos and printed materials. Therefore, any individual teacher could implement a lab activity in a very straightforward way and also supplement the lesson with a range of worksheets, additional readings, links to resources, and so on. While the full curriculum for teachers exists only in English language, the student worksheets, lab instructions, and data sheets were also developed in Thai as a part of the APEI project itself. Graduate teachers of the IEI program in Hawaii often comment on the completeness of lesson plans and materials within IEI which make lesson implementation very direct. The kits and support given to APEI teachers were intended to make classroom implementation as painless as possible.

## **Evaluation**

MEDB adapted the *Guide to Conducting Culturally Responsive Evaluations* from the 2002 User-Friendly Handbook for Project Evaluation, created by the National Science Foundation, to develop APEI’s evaluation process, which can be found in the Appendices. The overall process was to appropriately plan, implement, and reflect upon evaluations, with qualitative and quantitative assessments administered to educator and student recipients throughout the pilot phase. There was an overarching theme to continuously analyze, discuss, and integrate evaluations results in order to readily improve the APEI program.

The evaluation cycle included:

- Process Evaluation—MEDB staff de-briefed at the conclusion of each workshop day.
- Progress Evaluation—APEI teacher participants reflected on the workshop at the conclusion of each day.
- Summative Evaluation Phase 1—A final workshop evaluation was distributed to APEI educators.



- Summative Evaluation Phase 2a—APEI educators evaluated students at the conclusion of classroom implementation.
- Summative Evaluation Phase 2b—APEI educators were given assessments at the conclusion of classroom implementation.

## **Results and Discussion**

### **Implementation**

As of April 2014, 37 total APEI activities had been implemented across all eight APEI participating schools. The lesson implementation was broken down as follows:

- Solar Hot Water: 8
- Pinwheel: 8
- Wind Turbine: 8
- PV Panel: 8
- Energy Audit: 5

### **Student Response**

151 APEI student participants responded to the 2013-14 Student Unit Evaluation. 49.6% of these students were male and 50.3% were female. 31.7% were in M2 (equivalent to United States 7<sup>th</sup> grade) and 68.2% were in M3 (equivalent to United States 8th grade). These student respondents had participated in one or more of the following APEI curriculum activities:

- Wind turbine inquiry: 31.8%
- Pinwheel inquiry: 31.1%
- Solar oven: 17.9%
- Photovoltaic inquiry: 7.9%
- Solar hot water heater inquiry: 6.6%
- Energy audit: 4.6%

When asked “How interesting would you rate this lab activity?” on a scale from 1 “Not Interesting” through 5 “Very Interesting,” students responded with an average score of 4.6.

When asked “What did you like best about the lab activity?” students responded:

- Changing our design: 43%
- Building our model: 33.8%
- Testing our model: 13.2%
- Making a hypothesis: 10%

Regarding inquiry learning and its impact on student attitudes, one result from among survey answers of participating students stands out. To the question, “What did you like best

about the lab activity?" 43% of students selected "Changing our design." This strongly supports the concept that students are motivated to learn science by having authority to learn as scientists learn, by asking and answering their own questions, and by modifying their experiments to expand their own learning. This is the key to inquiry learning.

#### Educator Response

Seven of the eight APEI educator participants responded to the 2013-14 End of Academic Year assessment. 57% of the teachers taught M2, and 43% taught M3. In total, more than 350 students participated in APEI lessons. The following APEI equipment was used in lesson implementation:

- Pinwheel Materials: 16 %
- Wind Turbine Kits: 16%
- Multi-meter: 16%
- PV Panels: 16%
- Solar Hot Water Kit: 13%
- PowerPro Meter: 10%
- iPad Camera App: 10%
- iPad Clean Energy App: 3%

The APEI educators implemented a diverse array of lessons instead of heavily depending on a specific activity. This demonstrates APEI'S applicability to a wide range of classroom environments with recipients from a multiple grade-levels as well as differing geographic and socio-economic backgrounds.

When asked "How interesting were the APEI lessons for your students?" with 1 being "Not" Interesting" and 5 being "Very Interesting," the educators answered an average of 4.7, with two educators responding "Interesting," and five educators responding "Very Interesting."

When asked "How likely are you to teach APEI lessons again next year?" 29% of respondents answered "Likely" and 71% answered "Very Likely." 57% "Would recommend" and 43% "Would highly recommend" the APEI program, including the workshop, materials, and lesson planning to other teachers in their subject.

#### Conclusion

A first-year pilot of the Asia Pacific Energy Inquiry project has successfully accomplished the project mission, *A pilot program to explore and share universal learning techniques in a global setting*. The first grouping of eight Thai and Lao PDR teachers have used renewable energy lessons from the APEI curriculum to expand inquiry learning methods in their classes.

Inquiry learning is under increasing scrutiny among educational professionals. "...science education paradigm has been slowly shifting from studying science as a body of content to studying



science as the way scientists work, which is well known as ‘inquiry approach’...the student outcomes as they can perform inquiry-based tasks as a scientist, solve problems systematically, make decisions based on evidence and articulate their ideas of inquiry are qualities that teachers want their students to be capable of” (Junnang, 2014, p.1).

During school visits to APEI classrooms, through the study of lesson plans delivered by teachers, and within APEI teacher meetings in Chaing Mai and Bangkok, the evidence and observations of this project leads to several important conclusions.

1. APEI teachers responded well to their training. They carefully considered their normal curriculum, chose beneficial renewable energy inquiry activities, and inserted these activities at appropriate times for their own courses. Students modified their designs, asked and answered their own questions, and reported their findings—steps taken by “real scientists.” Teachers reported high levels of engagement among students of all levels.
2. Follow-up was important. Team members from IPST and MEDB monitored APEI teacher progress in implementing lessons, to maintain project momentum in the weeks following the September workshop. As a result, teachers shared progress, transmitted classroom photos, and commented on their experiences. Additionally, the face-to-face review sessions with APEI teachers on two occasions helped cement learning and validate teaching methodology within the group.
3. Teachers showed creativity in implementing APEI lab activities. The APEI labs, curriculum guide, materials, and worksheets translated to Thai language enabled teachers to build lessons which directly followed APEI guidelines, and several APEI teachers used the exact methods of the curriculum. However, some teachers—similar to teachers in Hawaii—chose to modify worksheets or provide links or introductory activities specifically matched to their own coursework. This is a very typical outcome and intention of the curriculum, which gives teachers some flexibility in best meeting the needs of their students and courses while introducing the important concepts of inquiry learning. During review sessions, the teachers were able to learn from each other their successful implementation ideas and methods.
4. Lab kits and materials provided to teachers were very suited to exploring inquiry learning through renewable energy. Pinwheel kits, wind turbines, Power Pro analyzers, photovoltaic panels, and solar heating kits were all sampled by students and found very informative, enjoyable, and eminently suitable in representing energies which are actively evolving in Asia. In at least one case, however, the classroom enrollment size proved too large for the number of kits provided in this pilot APEI project, and the teacher had to rotate lab teams among the available lab kit materials.

With these conclusions, there are also some ongoing discussion items which should be considered as APEI matures. The results of the first year help direct ideas to continue or expand APEI within Thailand or among other ASEAN nations.

1. APEI workshop training sessions could be expanded in size. The first APEI workshop in September 2013 involved only eight teachers in order to try the program methods with a select group. However, experience with many IET workshops in Hawaii shows that a teacher grouping of 20-25 attendees is very manageable, and in fact leads to much more interaction,

enthusiasm, and fun for the learning group. Even larger workshop groupings could be considered, with teams rotating among lab workstations.

2. ASEAN students and teachers from all levels could benefit through APEI activities. The pilot workshop featured excellent, experienced science teachers, and most were from high-level schools. Anecdotal evidence from the teachers suggests that rural students, perhaps less competitive in typical academic settings, become very engaged with science specifically because of the hands-on, open-ended inquiry activities of APEI. Therefore, ongoing workshops should incorporate a realistic cross-section of students to better gauge the impact of the program.
3. Some teachers easily matched APEI lessons to their courses, others enjoyed less curriculum flexibility. There was a range of science subjects taught, and therefore the inquiry activities of APEI—including renewable energies topics—fit better for some teachers than for others. Rigidity of normal course content caused some teachers to incorporate APEI only within a few of their classes, or even as activities during elective time or after-hours with students. Inquiry learning is of course most effective if it can be implemented with the widest possible reach, resulting in common science enthusiasm, vocabulary, practices, and skills among many students.

Overall, the APEI pilot project shows that inquiry methods already being practiced in Hawaii through Island Energy Inquiry™ have had positive impact in select Thai and Lao PDR classrooms, shown by data presented in this report. As Thanee Junnang notes in his Doctoral Dissertation, "...teachers as professionals need collective and individual support in the classroom. Designing inquiry-based lesson plans is the first step of practicing inquiry, which seems to be a crucial step needing support from experts" (Junnang, 2014, p.79).

Through the Asia Pacific Energy Inquiry pilot program, teachers have received the expert and ongoing help needed to successfully design, deliver, and enjoy the benefits of hands-on, culturally-relevant inquiry learning based on renewable energy technology in the Asia Pacific region.



## List of Appendices

A. APEI Workflow Timeline

B. APEI Evaluation Process

C. APEI Workshop Conclusion Evaluation

D. APEI Student Evaluation

E. APEI Educator Evaluation

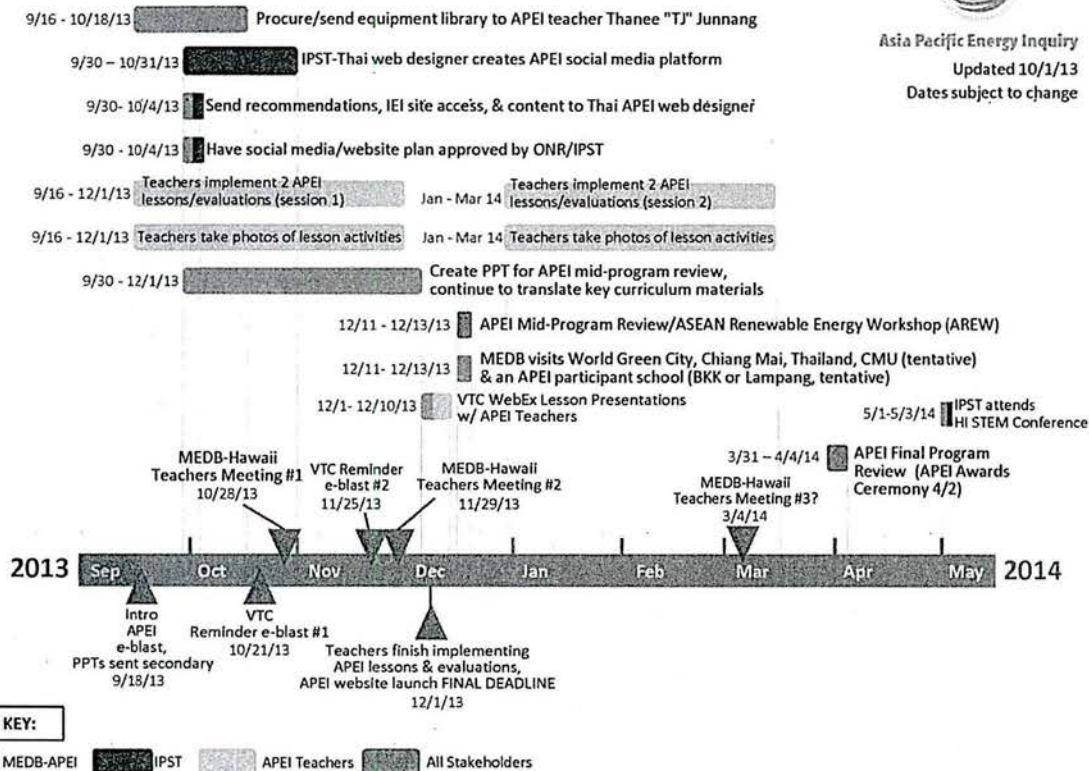
F. MEDB Inquiry Science Diagram

## A. APEI Workflow Timeline

### APEI-Thailand 2013-14 Workflow Timeline

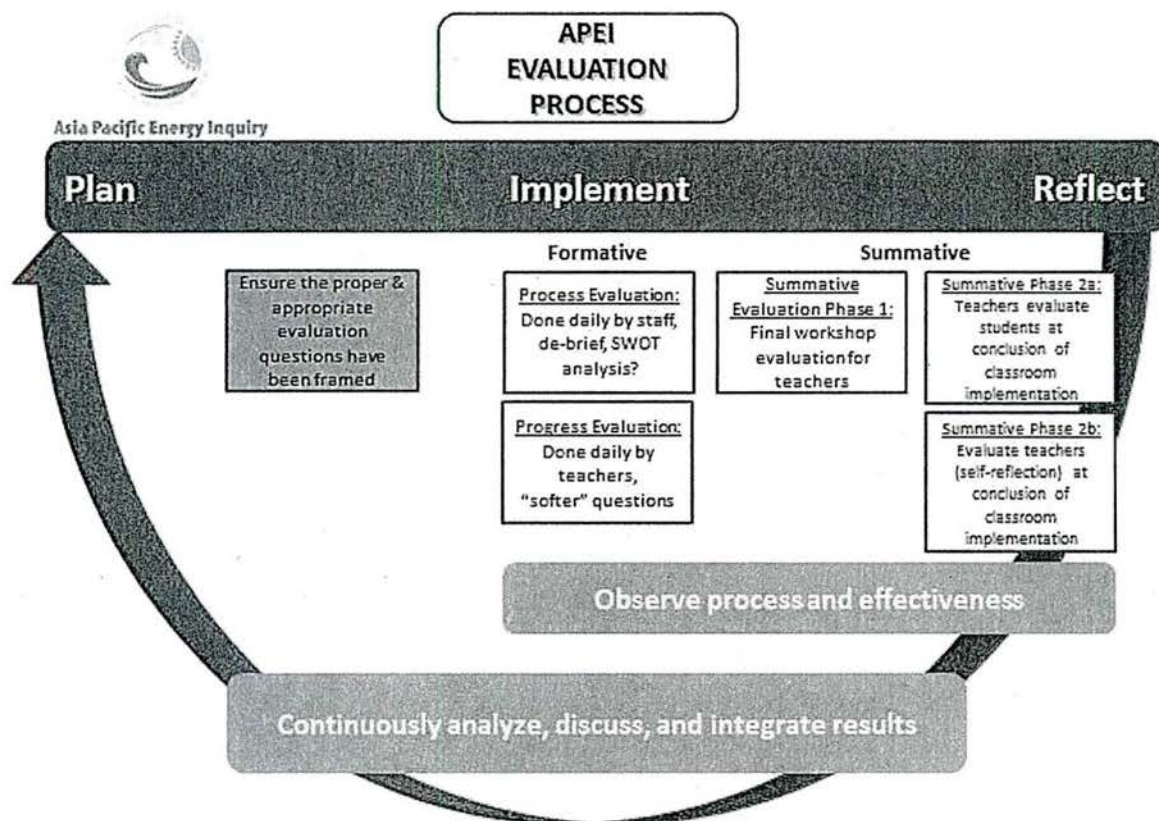


Asia Pacific Energy Inquiry  
Updated 10/1/13  
Dates subject to change





## B. APEI Evaluation Process



Reference: Frierson, H. T., Hood, S., & Hughes, G. B. (2002). A Guide to Conducting Culturally Responsive Evaluations. 2002 User-Friendly Handbook for Project Evaluation (63-76). Arlington, VA: Division of Research, Evaluation and Communication, National Science Foundation.

### C. APEI Workshop Conclusion Educator Evaluation

Question 1: I have a clearer understanding of energy sources and uses.

1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not Sure

Question 2: I have a clearer understanding of gender influences on science learning in the classroom.

1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not Sure

Question 3: I am more confident in my methods to involve girls and under-represented groups in science learning.

1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not Sure

Question 4: Energy education in science classes is:

1. Very Important 2. Somewhat Important 3. Mostly Unimportant 4. Unimportant 5. Not Sure

Question 5: I have improved my ability to implement inquiry-based science:

1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not Sure

Question 6: I would recommend this course to other teachers in my field.

1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not Sure



#### D. APEI Student Evaluation

Question 1: What lab activity did you complete?

- Pinwheel inquiry
- Wind turbine inquiry
- Photovoltaic inquiry
- Solar hot water inquiry
- Other

Question 2: What did you like best about the lab activity?

- Building our model
- Making a hypothesis—deciding what to test
- Testing our model, making measurements, and writing the data
- Changing our design to improve it

Question 3: How interesting would you rate this lab activity?

1. Not Interesting 2. Barely Interesting 3. Somewhat Interesting 4. Interesting 5. Very Interesting

Question 4: What science concept or idea did you learn from the lab activity?

Question 5: How did the lab activity help you learn?

Question 6: How could this lesson be improved to help other students learn better?

Demographic Information:

Question 7: What is your gender?

- Male
- Female

Question 8: Where do you attend school?

- Bantakloy School
- Bodindecha (Sing Singhaseni) School
- Lampang Kanlayanee School
- Princess Chulaborn's College
- School for Gifted Students, Dongdok Campus

Question 9: Which grade are you in?

- M1
- M2
- M3
- M4
- M5
- M6
- Other



#### E. APEI Educator Evaluation

Question 1: What is your gender?

- Male
- Female

Question 2: Where do you teach?

- Bantakloy School
- Bodindecha (Sing Singhaseni) School
- Lampang Kanlayanee School
- Princess Chulaborn's College
- School for Gifted Students, Dongdok Campus

Question 3: Which grades do you teach (check all grades that you teach)?

- M1
- M2
- M3
- M4
- M5
- M6
- Other

Question 4: How many students did you teach APEI lessons to in the past year?

- 0-50
- 50-100
- 100-150
- 150-200
- 200-250
- 250-300
- More than 300

Question 5: How many total students did you teach last year (APEI and non-APEI)?

- 0-50
- 50-100
- 100-150
- 150-200
- 200-250
- 250-300

- More than 300

Question 6: What equipment did you use to help students learn APEI lessons (indicate all items you used)?

- Pinwheel materials
- Wind turbine kits
- Photovoltaic panels
- Solar hot water kit
- Multi-meter
- PowerPro meter
- iPad Clean Energy app
- iPad camera app

Question 7: What data sheets did you use (indicate all items you used)?

- 1.2 Energy Audit
- 1.3 Energy Audit
- 1.2 PV Cell Inquiry
- 3.1 PV Cell Inquiry
- 3.2 PV Systems
- 2.1 School PV System
- 3.1 Solar Water
- 3.2 Solar Water
- 1.2 Wind Turbine
- 4.1 Wind Turbine

Question 8: How interesting were the APEI lessons for your students?

1. Not Interesting 2. Barely Interesting 3. Somewhat Interesting 4. Interesting 5. Very Interesting

Question 9: How likely are you to teach APEI lessons in the next year?

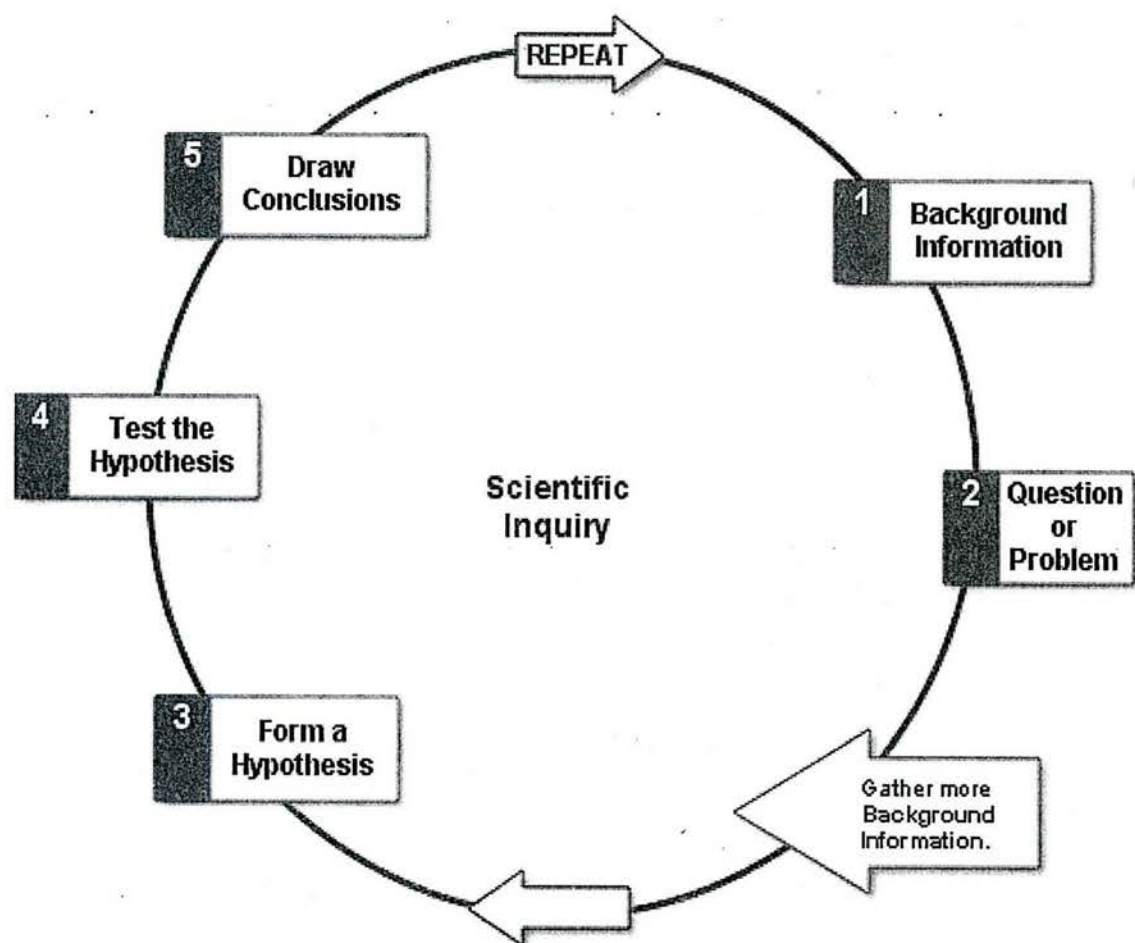
1. Not Likely 2. Likely 3. Very Likely

Question 10: How would you recommend the APEI program (workshop, materials, curriculum, lesson planning) to other teachers in your subject?

1. Not Recommend 2. Recommend 3. Highly Recommend



F. MEDB Inquiry Science Diagram



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